

UNCLASSIFIED  
SECURITY CLASSIFICATION

1770 F COPY

1

AD-A215 210 TIC  
DECLASSIFIED  
DEC 08 1989  
B D

Form Approved  
OMB No. 0704-0188

1b RESTRICTIVE MARKINGS		
3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; Distribution is unlimited		
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE		5. MONITORING ORGANIZATION REPORT NUMBER(S)
4. PERFORMING ORGANIZATION REPORT NUMBER(S)		
6a. NAME OF PERFORMING ORGANIZATION USA Research Institute of Environmental Medicine	6b. OFFICE SYMBOL (If applicable) SGRD-UE-NR	7a. NAME OF MONITORING ORGANIZATION US Army Medical Research & Development Cmd.
6c. ADDRESS (City, State, and ZIP Code) Natick, MA 01760		7b. ADDRESS (City, State, and ZIP Code) Fort Detrick Frederick, MD 21701-5012
8a. NAME OF FUNDING/SPONSORING ORGANIZATION	8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)		10. SOURCE OF FUNDING NUMBERS
		PROGRAM ELEMENT NO 63002D
		PROJECT NO 3M263002 D819
		TASK NO. AI
		WORK UNIT ACCESSION NO. DA305222
11. TITLE (Include Security Classification) CARBOHYDRATE-ELECTROLYTE SOLUTIONS DURING FIELD TRAINING: INTRODUCTION		
12. PERSONAL AUTHOR(S) Rose MS, Szlyk PC, Francesconi RP, Matthew W, Schilling D, Whang R		
13a. TYPE OF REPORT Final	13b. TIME COVERED FROM Jun 88 TO Aug 89	14. DATE OF REPORT (Year, Month, Day) 1989 August 22
15. PAGE COUNT 15		
16. SUPPLEMENTARY NOTATION		
17. COSATI CODES		
FIELD	GROUP	SUB-GROUP
18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) field training, heat, WBGT, glucose beverages, Army Reserves carbohydrate electrolyte solutions, hot weather		
19. ABSTRACT (Continue on reverse if necessary and identify by block number) The rationale and methods of evaluating two carbohydrate-electrolyte (CE) solutions at a field training exercise in hot weather are presented in this introductory article. Information on the development of the CE solutions are presented. The results are presented in a series of articles dealing with 1) acceptability of carbohydrate-electrolyte solutions and their effect on electrolyte homeostasis, 2) hypohydration during field training exercises in hot weather, and 3) field assessment of wet bulb globe temperature (WBGT). s. 12 p. 4		
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT <input checked="" type="checkbox"/> UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT <input type="checkbox"/> DTIC USERS		21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL LTC Madeleine S. Rose, AMSC		22b. TELEPHONE (Include Area Code) 508-651-4979
		22c. OFFICE SYMBOL SGRD-UE-NR

DD Form 1473, JUN 86

Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

20030204024

00 17 25 023

(508)651-4986  
#pages:15  
#words:2251  
#tables:2  
#figures:0  
#references:16

CARBOHYDRATE-ELECTROLYTE SOLUTIONS  
DURING FIELD TRAINING: INTRODUCTION

LTC Madeleine S. Rose, Ph.D., AMSC<sup>1</sup>

Patricia C. Szlyk, B.A., Ph.D.<sup>1</sup>

Ralph P. Francesconi, M.S., Ph.D.<sup>1</sup>

William Matthew, B.S.<sup>1</sup>

MAJ Dan Schilling, D.V.M., VC<sup>2</sup>

COL Robert Whang, M.D., MC, USAR<sup>3</sup>

Heat Research and Military Nutrition Divisions, US Army  
Research Institute of Environmental Medicine, Natick,  
MA<sup>1</sup>; Food Engineering Directorate, Natick RD&EC,  
Natick, MA<sup>2</sup>; 44th Evacuation Hospital, 807th Medical  
Brigade, Oklahoma City, OK<sup>3</sup>

Correspondence: Patricia C. Szlyk, Heat Research  
Division, USARIEM, Natick, MA 01760

Running head: Carbohydrate solutions in hot weather

Keywords: field training, heat, WBGT, carbohydrate-  
electrolyte solutions

#### HUMAN RESEARCH AND DISCLAIMER STATEMENTS

The views of the authors do not purport to reflect the positions of the Department of the Army or the Department of Defense. Human subjects participated in this study after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 in Use of Volunteers in Research.

# ABSTRACT

The rationale and methods of evaluating two carbohydrate-electrolyte (CE) solutions at a field training exercise in hot weather are presented in this introductory article. Information on the development of the CE solutions are presented. The results are presented in a series of articles dealing with 1) acceptability of carbohydrate-electrolyte solutions and their effect on electrolyte homeostasis, 2) hypohydration during field training exercises in hot weather, and 3) field assessment of wet bulb globe temperature (WBGT).



Accession For	
DTIS GRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By _____	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

fr 1473

4

The ability of a field unit to determine the intensity of heat stress and to maintain water discipline under these conditions is essential to its efficiency in combat. Maintenance of normal fluid and electrolyte balance in the combat soldier is crucial, especially in hot environments. First, replacing sweat losses of both water and electrolytes with appropriate carbohydrate-electrolyte (CE) solutions may be necessary to maintain the integrity of the extracellular fluid compartment. Additionally, there are regions of the world where extreme heat conditions are coupled with a high likelihood of diarrheal diseases. Exposing dehydrated troops to additional gastrointestinal losses predisposes them to further dehydration, depletion of extracellular volume, and possibly shock. Finally, combat troops are obviously at risk for traumatic blood loss and hemorrhagic shock. The risk from hemorrhagic shock is magnified in the presence of preexisting volume depletion (1). Soldiers encapsulated in chemical/biological protective suits have high sweat rates due to the head load attendant with wearing this protective clothing. Replenishment of sodium and maintenance of blood glucose is difficult

Keywords:

Sweat rates, dehydration

under these conditions since encapsulated soldiers are forced to fast until a protective shelter can be reached or until the threat has passed. In 1982 a National Research Council (NRC) advisory committee recommended a CE solution for consumption by these encapsulated troops (2). To distribute different solutions to meet all the above needs would be an overwhelming task and therefore we formulated and tested a multipurpose oral rehydration CE powder. The various uses of CE are: 1) primary replacement of fluid and electrolyte losses which occur while encapsulated in chemical protective gear; 2) supplemental replacement of heat-induced fluid and electrolyte losses; 3) treatment of mild heat casualties; and, 4) oral rehydration therapy for diarrheal losses.

The CE solution recommended by the NRC committee (CE2) was expected to replace minimal needs, not to replenish all fluid, carbohydrate, and sodium losses during encapsulation. Since soldiers working in the heat were expected to eat during the day, CE2 represented a basic solution. Additional electrolytes were added to CE2 to produce a solution (CE1) to treat

heat injuries. Doubling the strength of the CE1 solution (by reducing the amount of water mixed with the powder) would provide a solution that would be effective in treating diarrheal losses. The following information was taken into consideration when formulating CE1 (3-12): 1) sodium to maintain the integrity and volume of the extracellular fluid compartment; 2) potassium to assure intracellular volume and normal cardiovascular, neuromuscular, CNS, and gastrointestinal function; 3) magnesium to maintain normal intracellular enzyme activity and metabolism, prevent Mg-deficient hypokalemia, and maintain CNS function; and, 4) glucose as a modest source of energy under field conditions, to increase gastrointestinal absorption of Na and water, and to promote the active transport of K into cells.

For prevention and treatment of mild to moderate heat injuries in encapsulated or heat-stressed soldiers, an electrolyte concentration of 20, 10, and 2 mEq/L of  $\text{Na}^+$ ,  $\text{K}^+$ , and  $\text{Mg}^{++}$ , respectively, with carbohydrate levels at 25 g/L appears to meet all needs. Doubling the strength of the CE1 solution would provide a solution with a composition very similar to

the oral rehydration solution recommended by the World Health Organization (13). The advantages of this multipurpose, oral rehydration powder are: 1) individual packaging to prevent contamination and errors in mixing; 2) multiple uses; 3) simplicity in diluting the powder in a canteen of water; and 4) ease of distribution through normal supply channels. In fact, constraints on the weight carried by the combat infantryman played a role in the formulation of a multi-use and multi-strength CE powder.

CE solutions may improve soldier performance and fluid consumption in the heat but weather also has a profound effect. The ability to measure heat stress levels across a large area would provide valuable information for optimizing soldier performance. A close correlation between field and satellite-derived WBGT readings would indicate significant potential for the use of satellite remote sensing technology to accurately assess WBGT in training/operational environments.

A series of studies were conducted in collaboration with reservists of the 44th Evacuation Hospital, 807th Medical Brigade during field training



exercises (FTX) in June 1988. A team of military scientists and laboratory technicians from the US Army Research Institute of Environmental Medicine, Natick, MA studied the daily food intakes, serum changes pre- to post-FTX, and urinary variables twice daily of reservists doing moderate work under variable heat stress conditions at Fort Hood, Texas. Results of the studies are presented in the following series of articles dealing with 1) acceptability of CE solutions and their effect on electrolyte homeostasis, 2) hypohydration during field training exercises in hot weather, and 3) field assessment of wet bulb globe temperature (WBGT).

#### METHODS

Sixty-one reservists of the 44th Evacuation Hospital (Oklahoma City, OK and El Paso, TX), 807th Medical Brigade, participated in an 8 day field training exercise (FTX) at Fort Hood, TX during June 1988. All subjects were briefed on the design, testing procedures and risks, and signed a statement of informed consent retaining the right to withdraw from the study at any time without retribution. To make the

groups comparable in terms of activity level, age, gender, and work experience, subject assignment to the test beverage groups was made according to military rank, gender, age, and Military Occupational Specialty. Demographics and physical characteristics are presented in Table 1.

Table 1  
Descriptive Characteristics of Reservists

		CE1 (n=14)	CE2 (n=18)	W (n=17)	FW (n=12)	COMBINED (n=61)
Age (yrs)		34.3 $\pm 2.6$	33.3 $\pm 2.1$	34.1 $\pm 2.5$	37.3 $\pm 2.6$	34.6 $\pm 1.2$
Height (cm)		169.2 $\pm 1.8$	176.6 $\pm 2.6$	178.4 $\pm 3.3$	175.6 $\pm 3.1$	173.5 $\pm 1.5$
Weight (kg)		68.4 $\pm 3.1$	78.5 $\pm 3.7$	78.4 $\pm 4.2$	74.9 $\pm 4.2$	75.4 $\pm 2.0$
Sex:						
Male	No.	7	11	8	6	32
Female	No.	7	7	9	6	29
Point of Origin:						
El Paso	No.	6	3	6	3	18
OK City	No.	8	14	11	9	42
Other	No.	0	1	0	0	1

We evaluated two CE (CE1 and CE2) solutions, a flavored water placebo (FW), and chlorinated Water (W) in the current field trial (Table 2). Subjects were assigned to one of the 4 test groups which differed only in the test beverage assigned for ad libitum consumption. Subjects were also allowed to drink field chlorinated water or other beverages (juice, soda, milk, etc.).

Table 2  
Composition of Solutions Provided  
During 8-days of Field Training

Beverage	Electrolytes (mEq/L)						Glucose (g/L)
	Na <sup>+</sup>	Cl <sup>-</sup>	Mg <sup>++</sup>	PO <sub>4</sub> <sup>3-</sup>	HCO <sub>3</sub> <sup>-</sup>	K <sup>+</sup>	
CE1	22.8	24	5.2	3.2	10	9.5	25
CE2	25.0	24	0.14	2.0	0	0.02	25
FW	0	0	0	0	0	0	0
W	0	0	0	0	0	0	0

CE1 was composed of 2.5% maltodextrins with an osmolality of 127 mOsm/kg. CE2 contained a 2.5% fructose/maltodextrin mixture with an osmolality of 166 mOsm/kg. FW was a colored, lemon-lime flavored, low caloric (aspartame) drink which was similar in appearance and flavor to the CE1 and CE2 solutions. The FW group was included to determine the effects of coloring and flavoring on fluid intake. Packets of CE1 and CE2 powder were issued to the subjects twice daily. FW was pre-mixed and available at three locations in thermos jugs. All water consumed was field grade water treated by chlorination and stored in water buffalos and 36 gallon lyster bags. Subjects were instructed to consume their assigned beverage ad libitum but were also allowed to drink any other available fluids.

Soldiers lived in tents for 8 days during the FTX at Fort Hood, TX. During this time, they constructed an Evacuation Hospital, attended training sessions (Days 1-5) in air-conditioned classrooms, and participated in an FTX (Days 6-8). During the afternoon (1400-2200 hrs) of Day 5, most soldiers were allowed free time and many were transported to the main post. The physical activity of the soldiers ranged

from light to heavy (classroom lectures to setting up hospital tents) exertion with the overall pattern in the moderate range. Heat stress was variable with periods of mild to intense heat stress (maximum WBGT, 78.5°-90.3°F) encountered during the 8 days in the field.

The first article of this series covers the acceptability of carbohydrate-electrolyte solutions and their effects on blood indices (14); hypohydration during field training exercises in hot weather is the topic of the second article (15); and the final article covers heat casualties and field assessment of WBGT (16). The presentation of temperature as degrees Fahrenheit in these articles is a departure from scientific convention but was done to be consistent with current military terms of reference on heat stress and instrument scales.

#### Acknowledgement

The authors wish to express their appreciation to all of the participants in this study. We also extend our appreciation to BG Randall Phillips, commander of

the 807th Medical Brigade; COL Duane May, commander of the 44th Evacuation Hospital; and LTC Paul Boensch II, Executive Officer of the 44th Evacuation Hospital. Dr. Armand Cardello and Dr. Richard Popper of the U.S. Army Natick Research, Development and Engineering Center deserve special thanks for conducting a pre-test sensory evaluation of the electrolyte and placebo solutions. We also wish to thank Ms. Viola Jim for her assistance in preparing parts of this manuscript. We appreciate the help of Dr. Kenneth Rider, Director of the Pathology Laboratory, Wishard Memorial Hospital, Indianapolis, IN for assistance in analyzing the blood samples.

#### REFERENCES

1. Guyton AC: Textbook of Medical Physiology, Sixth Edition. Philadelphia, PA, W.B. Saunders Co., 1981
2. Conclusions and recommendations arising from a workshop, held June 3-4, 1982, to determine nutritional requirements of military personnel in protective clothing. Committee on Nutritional Requirements in Protective Clothing, Food and Nutrition Board, Commission on Life Sciences, National Research Council.

3. Kutsky RJ: Handbook of Vitamins, Minerals and Hormones, 2nd Edition. New York, Van Nostrand Reinhold, 1981.
4. Whang R, Welt LG: Observations in experimental magnesium depletion. J Clin Inves 43:305, 1963
5. Ryan MP, Whang R, Yamalis W. Effect of magnesium deficiency on cardiac and skeletal muscle potassium during dietary potassium restriction. Proc Soc Exp Biol Med 143:1045-1047, 1973
6. Whang R, Morosi HJ, Rogers D, et al: The influence of continuing magnesium deficiency on muscle potassium repletion. J Lab Clin Med 70:895-902, 1967
7. Whang R, Flink EB, Dyckner T, et al: Magnesium depletion as a cause of refractory potassium repletion. Arch Int Med 145:1686-1689, 1985
8. Costill DL, Cote R, Fink WJ: Dietary potassium and heavy exercise: Effects on muscle water and electrolytes. Am J Clin Nutr 36:266-275, 1982
9. Kaufman CE, Felsenfeld AJ, Vannatta JB, et al: Maintenance of body fluid potassium, calcium, magnesium, and phosphorus in Pathophysiology, Third Edition, Edited by Frohlich ED. Philadelphia, PA, JB Lippincott, 1984

10. Whang R: Medical and health aspects of potassium in, Potassium in Agriculture, Edited by Munson RD. Madison, WI, American Society of Agronomy, 1985
11. Knochel JP: The pathophysiology and clinical characteristics of severe hypophosphatemia. Arch Int Med 137:203, 1977
12. Knochel JP: Potassium deficiency during training in the heat. Ann NY Acad Sci 301:175-182, 1977
13. Pierce NF, Hirschhorn N: Oral fluid--a simple weapon against dehydration in diarrhoea. WHO Chronicle 31:87-93, 1977
14. Rose MS, Szlyk PC, Francesconi RP, et al: Carbohydrate-electrolyte solutions during field training: Acceptability and effect on electrolyte homeostasis. Mil Med (present issue)
15. Szlyk PC, Francesconi RP, Rose MS, et al: Carbohydrate-electrolyte solutions during field training: Incidence of hypohydration. Mil Med (present issue)
16. Whang R, Matthew WT, Christensen J, et al: Field assessment of wet bulb globe temperature - present and future. Mil Med (present issue)